2006 Clean Snowmobile Challenge Design Paper

Derek Zimney, Derek Pederson, Chris Callender, Patrick Shaver, Shane O'Brien, Nate Warfield
University of Minnesota – Duluth SnowDogs

ABSTRACT

The focus of this design project was to reengineer a current production snowmobile to improve emissions and noise levels, while maintaining or increasing performance. To decrease emissions we added a universal automobile catalytic converter, with a forced air induction system. In addition, we also added a sound suppressing snow skirt to reduce chassis clatter and exhaust noise. Although the plan was not limited to these factors, they were the main implementations to the overall scheme.

INTRODUCTION

The 2006 Clean Snowmobile Challenge presented us with many interesting design implementations. From performance increase to sound reduction, the ranges of challenges were broad. We have advanced quite a ways from the origins of snowmobiling, since the first snowmobile was introduced in 1920's; with its main purpose as transportation. It was used to traverse over the wintry terrain while hunting, trapping, and other outdoor activities. The snowmobile was designed as an alternative to snowshoes or cross country skis. Since then, snowmobiling has evolved into the sport we know today. Rather than just a means of winter transportation it has become a recreational activity for more than four-million people across the world [1]. Last year in North America alone, over twenty seven billion dollars were spent on snowmobiles, related products, and vacations [1]. With the recent environmental concerns such as the dispute in West Yellowstone, it is apparent that the sport of snowmobiling must make a turn in the direction of a cleaner, quieter, more efficient machine. This is why we decided to compete in the Society of Automotive Engineer's (SAE) Clean Snowmobile Challenge. We realize that the future of our sport is in jeopardy and changes need to be made in order to preserve it. The snowmobile that we chose for this endeavor was a Polaris FST Classic. This sled, new for 2006, is a 750cc four stroke that is factory turbocharged. This snowmobile was chosen for its stock performance and future potentials. Four stroke engines are the future to motorsport internal combustion engines, as very apparent in the off-road motorcycle and all terrain vehicle industry, where they are steadily increasing year to year.

TECHNICAL OVERVIEW

Our main goal was to maintain the current performance of the FST while decreasing noise and emissions. Some of the minor aspects that we wanted to improve on the current design included adding another fan to the intercooler to increase cooling capacity and, in addition, boost performance by feeding cooler air into the air intake. By remounting the intercooler above the clutch guard, adding a fan, along with improved venting, this was accomplished. Another performance modification implemented was to increase the diameter of the exhaust system to create a free-flowing environment to minimize the effects of adding a catalytic converter. Whenever additional restrictions are added to the exhaust system, it creates more backpressure, decreasing engine performance and efficiency. Exhaust wrap was added to the bare pipe to keep under hood temperatures lower along with keeping the pipe and catalytic converter hotter. In turn this increases performance by getting the catalyst up to optimum temperature quicker. Not only does this help catalyst operation, but also takes away from excess engine heat.

The exhaust was a main concern for the team, as we wanted to create an ideally unrestrictive exhaust that drastically lowered emissions and still kept a practical design. We knew that by adding a catalytic converter we would be restricting exhaust flow, so we increased the pipe diameter from 5.08 cm to 5.72 cm to help balance out this restriction. This increase in diameter resulted in a 5.43 cm^3 increase in the volume of exhaust flow. Compared to the stock exhaust system, this gave us a 26.7% increase in exhaust volume.

Figure 1: Mount of Catalytic Converter and

Exhaust Pipe Routing

An added benefit of the heat wrapped exhaust was the ability to mount items closer to the exhaust system without fear of melting or burning. This was an important part of the design because it allowed us to route the intercooler air system parallel to the exhaust without fear of ill effects due to the heat (Figure 1). An aluminized heat wrap was implemented on the intercooler intake system to help keep the temperature within the intake lower by isolating it from the heat radiating from the exhaust.

Isolating the intake tract made it possible to gain a greater efficiency from the intercooler system and by the additional fan that was mounted to it. By using two fans we were able to create an air current under the hood that drew in cool, outside air across the intercooler and directly into the intake air filter. In addition, it helped move warm air to the exhaust side of the sled away from the air filter, being pushed across the engine by cooler air. The purpose of this was to double the airflow through the intercooler and to add additional cooling capacity to the intercooler and internal engine. The system was designed in such a way so that it blew through the intercooler to the intake air filter. This countered the fact that we removed the air box and removed the stock air filter in favor of more space for the intercooler. The mass airflow sensor was relocated into the elbow of the new air intake so that the ECU could measure our air intake through the turbocharger and adjust the fuel metering to appropriate levels. The mass airflow sensor was relocated into the elbow of the new air intake so that the ECU could measure our air intake through the turbocharger and adjust the fuel metering to achieve a stoichiometric or slightly rich air/fuel mixture. This wasn't a modification for performance but was a necessary modification for the snowmobile to run correctly. We had considered mounting the mass air flow sensor directly in the air filter but decided against it because of the complexity of the job and also because we wouldn't have a true measure of the air flow going into the turbocharger.

Adding a catalytic converter and extensively modifying the exhaust had consumed most of the space in the front of the engine compartment that had been occupied the intercooler. The stock mounting bracket for the intercooler was utilized to mount the catalytic converter in a stable position. Our next challenge was to mount the intercooler in a place where it would receive cool air and also be isolated from the majority of the engine and exhaust heat. We chose to mount the intercooler on the clutch guard because of the air tract that flows under the edge of the hood and over the clutch area. This gave us a cool air stream to work with and also isolated the intercooler from a fair amount of the engine heat. We mounted the two cooling fans underneath the intercooler to move the cool air coming from under the edge of the hood through the intercooler (Figure 2).

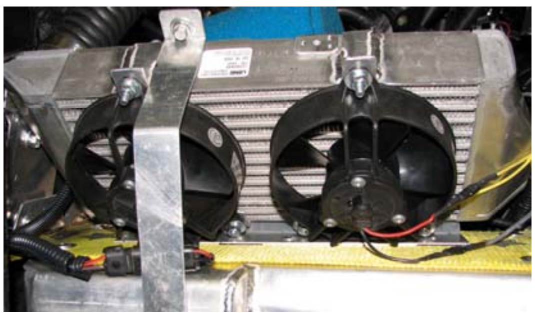


Figure 2: Left Hand View of Intercooler Mount

This forced the air to move through the intercooler and also increased the air flow through the air filter. By mounting the intercooler in this fashion we had effectively increased the amount of cool air moving into the air filter (Figure 3).

Figure 3: Right Hand View of Intercooler and Intake Air Filter

As the air flow continued past the air filter it moved the warm air radiating from the exhaust manifold and engine away from the air intake and intercooler. This air flow helps to keep some of the key components of the intake system cool, thus increasing efficiency. By changing one key component of the system, the location of the intercooler and fans, we had effectively gained many benefits that would have otherwise cost a great deal more to implement effectively.

EMISSIONS

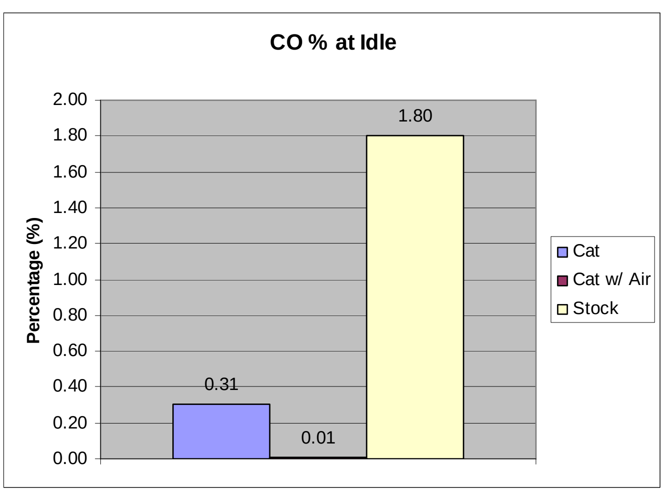
To decrease emissions we implemented a catalytic converter with an inlet for a supplemental air supply from an electrically driven air pump. We chose an electrically driven air pump because of the location restrictions of a mechanical design. The mechanical design would have forced us to redesign the stock exhaust resonator, which was beyond our time constraints. An electrical design gave us the flexibility to mount the air pump in any location with enough room to route the air supply hose to the catalytic converter. An electrical pump also gave us more control over the functioning of it as compared to a mechanical implementation. We found the optimal location to be in the very front of the engine compartment because it allowed cooling air to pass over the pump (Figure 4).

Figure 4: Catalytic Converter Forced Air Pump

The air pump was also sealed with silicon so snow dust coming under the hood wouldn't pose a problem. This location gave us the ability to intake air through a small breather filter located in the nose of the snowmobile (Figure 5).

Figure 5: Air Intake Filter for Forced Air Pump

The converter reduced emissions a fair amount from stock but the implementation of the air pump really helped to lower the emissions. This was most noticeable when the sled was run at an engine speed above 5000 rpm. To get the best performance out of our catalytic converter an engine warm-up period was necessary to get the catalyst up to operating temperature. The exhaust wrap helps to contain the heat of the exhaust system, in turn keeping the converter hot enough to operate at optimal temperature.



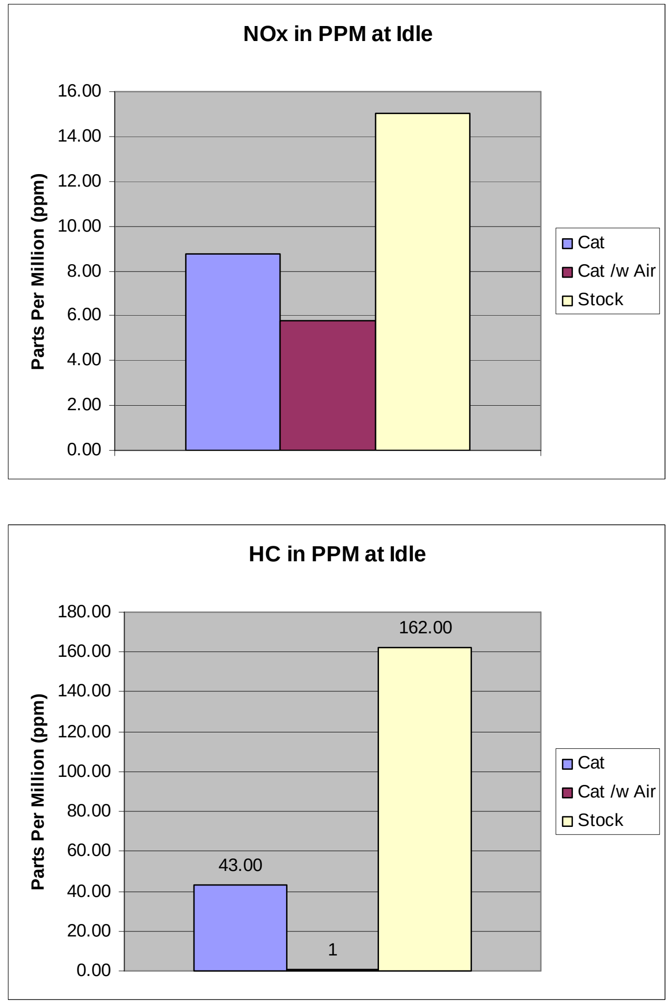


Figure 6: Exhaust Gases at 1500 RPM (Idle)

As it is visible from the given graphs the catalytic converter with the forced air gives the best emissions, especially at idle (approx. 1500 RPM). As we increase to about 5300 RPM, our CO and HC are significantly less with the catalytic converter and forced air. At this same RPM we get an increase in NO_x, compared to stock, but it is still an improvement over the catalyst with no forced air input.

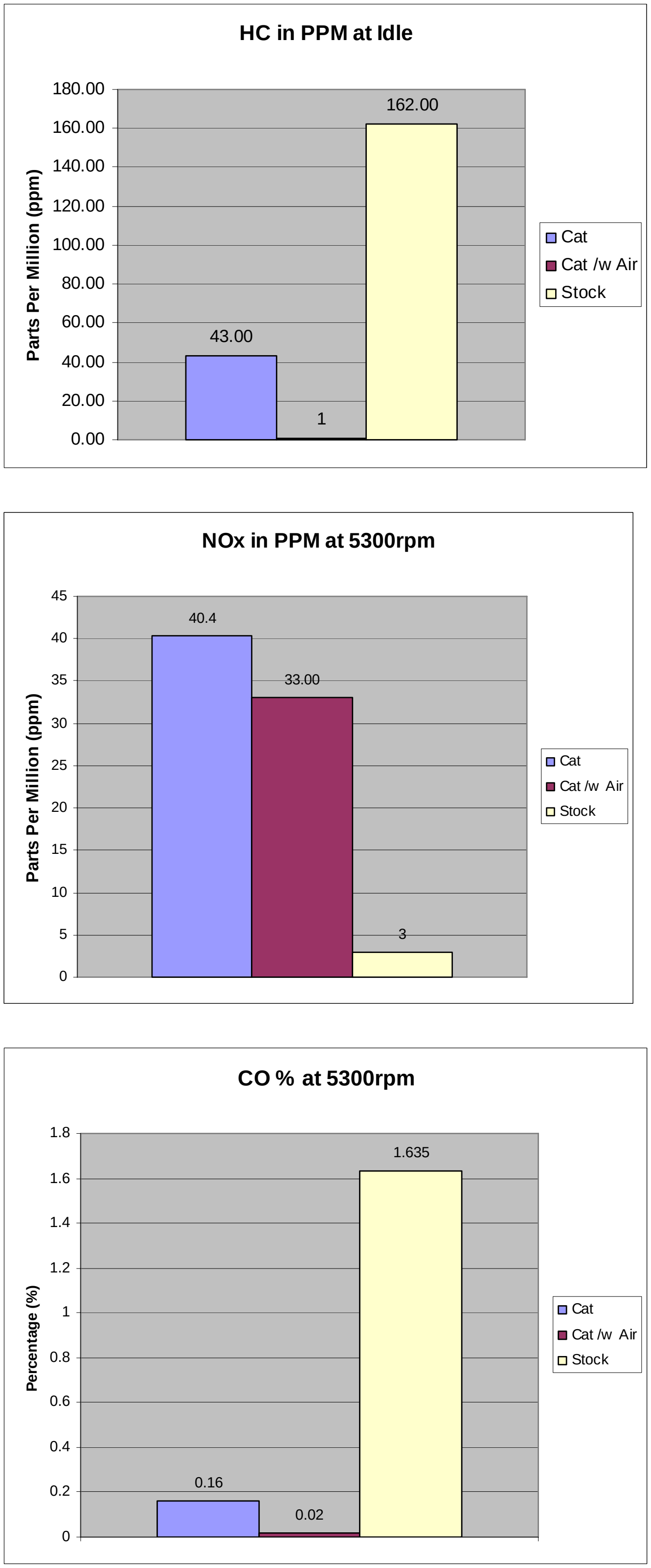


Figure 7: Exhaust Gases at 5300 RPM

Overall, we made a significant improvement in emissions by adding our three stage catalytic converter, with an even greater improvement by adding the forced air into the second catalyst (honeycomb) in the converter.

NOISE

We determined that a major source of the objective noise was created by the track clips hitting the plastic rail tips. This seems to be a problem on almost every production sled, and especially on this sled, having a fully clipped track. The addition of “jab” wheels, such as those used by drag racers to keep the track from sucking up into the tunnel and getting “jabbed” by the rail tips, seemed like a possible solution but didn’t provide the noise reduction that we desired. Instead we decided to implement a rubber skirt to contain the noise within the tunnel. The natural sound absorption of the rubber made it a natural selection for the skirt material. With this design, it not only blocks out track noise, but also minimizes exhaust noise even further. After adding the catalytic converter it managed to quiet down the sled even further, with the exhaust outlet barley audible to the ear over the engine.

CONCLUSION

Increasing performance while reducing emissions and noise isn’t something that is easily accomplished with bolt-on parts, it takes time, money, and a quality design process. Performance boosts usually equate to an increase in fuel usage, which also translates into an increase in emissions due to the extra fuel being burned. Additional performance also typically adds more engine/exhaust noise since the modifications are intended for performance and generally aren’t concerned with the noise level of the snowmobile. One of the major problems that we faced with the FST was the space limitation under the hood. It was determined that we wanted to have all of the performed modifications fit under the hood to have a logical fit and form to the sled. This was more difficult than originally believed, as Polaris had designed a streamlined snowmobile that didn’t leave much space underneath the hood for further expansion and design.

For our first year in the Clean Snowmobile Challenge our goal was simple, to "build a durable snowmobile with reduced sound and emissions, while maintaining stock performance and comfort." We had a number of modifications that we wanted to perform them and then listed them in the order of importance. This year we were able to improve emissions with the use of a catalytic converter and an air pump. We also were able to reduce track noise with the use of a rubber skirt under the running boards. We improved the efficiency of the intercooler and also improved the air intake into the turbo. We believe that these were considerable accomplishments given our time frame to complete them. For next year a hybrid electric drive has already been discussed. It would be a big project but something that we believe will propel the snowmobile industry forward. A better skirt design is also something that we would like to implement, and experiment with different materials to see which absorb noise better. During our testing we also noticed that the cool air going through the air pump seemed to be cooling down the catalyst, so we may try to test a hot air injection design to determine if that improves catalyst performance by keeping the catalyst at a hotter, more ideal operating temperature. These are some of the new ideas that we would like to try and implement for next year's competition. We would also like to refine our current designs to make the most durable, reliable snowmobile that we can. The 2006 Clean Snowmobile Challenge produced many unique challenges for the University of Minnesota, Duluth. It is our intentions to completely integrate our designs next year to avoid possible conflicts of design during manufacturing. By redesigning the snowmobile in this matter we will be able to integrate several systems and help reduce the cost associated with manufacturing many separate parts by combining them into one. This will cut down on manufacturing time, cost, and the extra weight associated with separate parts. Overall we feel confident in the quality of our product and would like to continue with this project next year.

ACKNOWLEDGMENTS

We would like to thank Polaris for their grateful donation of our project snowmobile, Kenwood Muffler and Exhaust for their help with our catalytic converter, Barker's Welding, Inc. for their superb aluminum welding, Strandlund Refrigeration, Heating, & Cooling for their generous donation, Silver Creek Embroidery for their custom polo donations, Dr. Stan Burns for his wisdom and guidance throughout the project, Facilities Management for allowing us a location and equipment usage, and Dr. Stan Burns, our academic advisor, for his wisdom and guidance throughout the project.

REFERENCES

1. International Snowmobile Manufacturers Association.
http://www.snowmobile.org/features_revenue.asp
Website accessed 2/28/06.